Sound absorption property of wood for five eucalypt species

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Abstract: The sound absorption coefficients of wood and wood boards for five eucalypt species (*Eucalyptus urophylla*, *Eucalyptus urophylla* × *E. grandis*, *Eucalyptus urophylla* × *E. tereticornis*, *Eucalyptus urophylla* × *E. camaldulensis* and *Eucalyptus cloeziana*) that were collected from plantation in Dongmen Forestry Center of Guangxi Province, China were tested with standing wave method and their sound absorption properties were also compared. The results showed that the sound absorption coefficients of the five eucalypt wood species did not change evidently below 1000 Hz, but above 1000 Hz their sound absorption coefficients increased with the increasing frequency. The difference in sound absorption coefficient among five species of eucalypt wood is not evident at the tested frequency range (200-2000 Hz), but the sound absorption property of *Eucalyptus urophylla* at low frequency is better than that of other four species. The sound absorption coefficient of the tangential-sawn board is higher than that of the radial-sawn board. The sound absorption property of eucalypt wood of 0.5 cm in thickness is much better than that of 1.0 cm in thickness. It is concluded that wood sound absorption properties of eucalypts are affected by their board thickness and the type of sawn timber within the testing frequency, but the variance of wood sound absorption property among the five tested species is not significant.

Keywords: Wood; Standing wave method; Sound absorption coefficient; Eucalypt plantation
CLC number: S781.38 **Document code:** A **Article ID:** 1007-662X(2004)03-0207-04

Introduction

It is well known that both language and music convey information, idea and feeling by sound to finish exchange, understanding and enjoyment. The control of sound in the construction structure is achieved by the acoustic absorption property in the inner face of fitment materials from buildings and houses. The spatial sound property of wood and wood-based materials can be assessed by their acoustic absorption. The acoustic absorption, namely acoustic absorption coefficient, is represented by the percentage of the surface reflection energy absorbed or not by the material of the incidence energy (Watanabe Haruto 1986). The past studies lay particular stress on the acoustic properties of several chemically modified Sitka spruce samples (Chang *et al.* 2000), dynamic elastic modulus and loss tangent of reed (Eiichi Obataya *et al.* 1999 and Shen Jun *et al.* 2001), and the acoustic properties of resonance spruce wood (V. Bucur *et al.* 1999), while reports on the acoustic absorption of wood and wood-based materials were very few.

Eucalypt wood is used not only for pulp and fiber but also for the joiner, furniture, flooring board, interior decoration,etc.. A larger area of eucalypt artificial forest has been planted in South China, covering 600 counties throughout 17 provinces and cities. This study tested the sound absorption properties of wood of five eucalypt species for the purpose to provide scientific data for proper utilization of the eucalypt wood resource and decrease of the environmental noise in houses.

Fundation item This study is Part of 2000-4-13 in "948" Project from the State Forestry Administration of P. R. China
Biography: JIANG Ze-hui (1939-), female, Professor in Research Institute of Wood Industry in Chinese Academy of Forestry. .
Received date: 2004-04-14
Responsible editor: Chai Ruihai

Material and method

Material

Five eucalypt species, including *Eucalyptus urophylla*, *Eucalyptus urophylla* × *E. grandis*, *Eucalyptus urophylla* × *E. tereticornis*, *Eucalyptus urophylla* × *E. camaldulensis* and *Eucalyptus cloeziana,* were collected from the plantation in Dongmen Forestry Center of Guangxi Province for testing sound absorption property. The sampling method was taken in accordance with the state standard GB1930~41-91. Sample size is Φ100 mm in diameter and 0.5 cm and 1.0 cm in thickness.

Method

Test method was taken in accordance with the state standard GBJ 88-85 "Measurement criterion of standing wave method for sound absorption coefficient and sound impedance". The standing wave method is a simple and economical method used to measure the vertical sound absorption coefficient; the sound absorption coefficient under random incidence is calculated according to the results measured. Each species has the radial-sawn board and the tangential-sawn board for test.

Test apparatus: Φ100 mm B & K 4002 Standing Wave Fitting, B & K 2010 Analysis Meter, GF–10 Power Amplifier

and B & K 2110 Audio Frequency Analysis Meter. Depth of test cavity: 95 cm

Results and discussion

Sound absorption property of different materials

When the sound wave meets the material surface, part is reflected back, part is absorbed and part is passed: The ability for absorption and sound reflection depends on the material. The acoustic absorption of common materials is listed in the Table 1. As it is seen from Table 1, the density of the brick, glass and polished wood is high while their acoustic absorption is low; the acoustic absorption of the untreated wood is lower than that of the polished wood because the paint changes the absorption of wood to sound; the carpet, wallboard and sound-absorbing wallboard have a good performance in the acoustic absorption.

Table 1 Acoustic absorption of fitment materials (Approximation)[1]

Materials	Acoustic absorption
Open window	1.00
Brick	0.03
Carpet	0.25
Glass	0.03
Wood	0.06
Polished wood	0.03
Wallboard	0.27
Sound-absorbing wallboard	0.20~0.90

[1] Watanabe Haruto,1986

Sound absorption property of eucalypt wood

In fact, all materials have the absorption to sound, but the difference is the extent of absorption. The absorption of materials is decided by their own properties; on the other hand, the absorption is also decided by the frequency and the incidence direction of the sound. Therefore, the sound absorption coefficient is an average of the absorption values from each direction, and it is specified under a certain frequency.

The sound absorption coefficients for five eucalypt wood species under different frequency are shown in Table 2. The sound absorption coefficients of the five eucalypt wood species did not change evidently below 1000 Hz, but above 1000 Hz their sound absorption coefficients increased with the increasing frequency. The study results are the same with the test results under common material tests (Ma 1983). Moreover, these five species of eucalypt wood were different in the sound absorption coefficient under different frequencies. At the range from 200 Hz to 1600 Hz the sound absorption coefficients of *Eucalyptus urophylla* and *Eucalyptus urophylla* × *E. grandis* were higher than these of the other three species. At 2000 Hz for the sound absorption coefficient the *Eucalyptus urophylla* × *E. tereticornis* was highest, followed by *Eucalyptus cloeziana*, and the lowest was *Eucalyptus urophylla*.. The variance for the sound absorption coefficient was further analyzed as described in Table 3. The results indicate that the difference in the sound absorption coefficient of different species is not significant under the tested frequency range.

Table 2. Sound absorption coefficients of different species of eucalypt wood

Species	Frequency (Hz)										
	200	250	315	400	500	630	800	1000	1250	1600	2000
Eucalyptus urophylla	0.030	0.033	0.023	0.030	0.017	0.020	0.017	0.017	0.035	0.073	0.042
Eucalyptu urophylla ×*E. grandi*	0.027	0.028	0.028	0.030	0.020	0.017	0.017	0.013	0.020	0.072	0.070
Eucalyptus urophylla×*E.tereticornis*	0.025	0.025	0.015	0.025	0.018	0.015	0.015	0.010	0.015	0.053	0.145
Eucalyptus urophylla×*E.camaldulensis*	0.023	0.022	0.020	0.013	0.012	0.015	0.010	0.013	0.013	0.053	0.078
Eucalyptus cloeziana	0.018	0.025	0.013	0.028	0.010	0.015	0.010	0.010	0.023	0.043	0.120

Table 3. Variance analysis for sound absorption coefficient of eucalypt wood

Source of error	Sum of square	Degree of freedom	Mean square	*F* value	Significance $F_{(0.05)}$
Between groups	0.000422	4	0.000105	0.143195	2.56
Internal groups	0.0368	50	0.000736		
Total	0.037221	54			

Sound absorption property of different eucalypt wood boards

Solid wood is often sawn into two kinds of boards, the quarter-sawn board and the back-sawn board. Comparison in sound absorption coefficient was made for the two kinds of boards (Table 4). The sound absorption coefficients of the back-sawn boards from five species were higher than or equal to these of the quarter-sawn boards at a frequency of 200-800 Hz; the change of sound absorption coefficient among the five species is of no clear rule at a frequency of above 800Hz. It can be thought that the sound absorption of the back-sawn board is better than that of the quarter-sawn board at a range of low frequency.

At the test range the sound absorption coefficient of the back-sawn board from *Eucalyptus urophylla* was higher

than that of its quarter-sawn board. At a frequency of 1250-1600 Hz the sound absorption coefficient of the quarter-sawn board from *Eucalyptus urophyllaxE.grandis* was higher than that of its back-sawn board; at 2000 Hz the sound absorption coefficient of the back-sawn board was higher than that of its quarter-sawn board. At a frequency of 1000-1600 Hz the sound absorption coefficient of the back-sawn board from *Eucalyptus urophylla* × *E. camaldulensis* was equal to or higher than that of its quarter-sawn board; at 2000 Hz the sound absorption coefficient of the quarter-sawn board was higher than that of its back-sawn board and reached the maximum showing the better sound absorption at high frequency range. At 2000 Hz the sound absorption coefficients of the quarter-sawn board and the back-sawn board from *Eucalyptus cloeziana* reach the maximum and the sound absorption is better than that at low frequency.

Tab.4 Sound absorption coefficient of different eucalypts wood boards

Species	Frequency (Hz)										
	200	250	315	400	500	630	800	1000	1250	1600	2000
Eucalyptus urophylla	0.010[1]	0.010	0.010	0.020	0.010	0.010	0.010	0.010	0.015	0.018	0.035
	0.030[2]	0.050	0.030	0.040	0.020	0.030	0.020	0.020	0.060	0.180	0.040
Eucalyptu urophyllaxE. grandi	0.010	0.015	0.015	0.020	0.010	0.010	0.010	0.010	0.020	0.155	0.055
	0.010	0.020	0.020	0.020	0.020	0.010	0.010	0.010	0.010	0.030	0.105
Eucalyptus urophyllaxE .tereticornis	0.025	0.035	0.015	0.025	0.015	0.010	0.010	0.010	0.010	0.065	0.110
	0.025	0.020	0.015	0.025	0.020	0.020	0.020	0.010	0.020	0.040	0.180
Eucalyptus urophyllaxE.camaldulensis	0.015	0.010	0.010	0.020	0.010	0.010	0.010	0.010	0.010	0.040	0.115
	0.025	0.025	0.020	0.015	0.015	0.015	0.010	0.010	0.010	0.100	0.090
Eucalyptus cloeziana	0.020	0.025	0.015	0.025	0.010	0.015	0.010	0.010	0.020	0.055	0.085
	0.015	0.025	0.010	0.030	0.010	0.015	0.010	0.010	0.025	0.030	0.155

Note: For each species the figure in first line[1] is for the radial-sawn board and the figure in second line[2] is for the tangential-sawn board.

It can be seen from the above analysis results that the sound absorption of the back-sawn board from *Eucalyptus urophylla* is better than that of its quarter-sawn board; the sound absorption change of two kinds of boards from other species is not evident at a frequency of 1250-2000 Hz.

Sound absorption property of eucalypt wood boards of different thickness

The sound absorption coefficients of the boards with different thickness decrease gradually at the increasing frequency from 200Hz to 1000 Hz, while at a frequency of above 1000Hz, the sound absorption coefficients increase slowly and the difference is more evident (Fig. 1). For the board 0.5 cm in thickness, its sound absorption coefficient at the high frequency was higher than that at the low frequency and the coefficient was obviously higher than that of the board 1.0 cm in thickness. At 1600 Hz the sound absorption coefficients of *Eucalyptus urophylla* and *Eucalyptus urophylla* × *E. camaldulensis* reached the maximum, and it indicates that the sound absorption coefficient at the high frequency is higher than that at the low frequency. In all, the acoustic absorption of boards of 0.5 cm in thickness is much better.

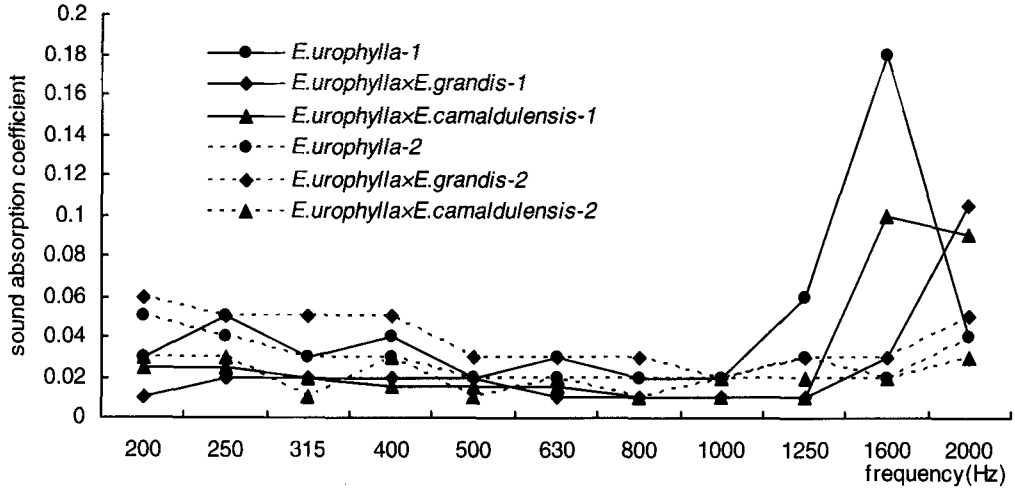

Fig. 1 Sound absorption coefficients of eucalypt boards with different thickness

Note: the solid line (1): 0.5 cm in thickness; the broken line (2): 1 cm in thickness

Fig. 2 shows that the relationship of acoustic absorption and frequency of plywood of 3 mm in thickness.When comparing Fig.1 and Fig.2, it is found that sound absorption coefficient of the plywood with a thickness of 3 cm at the low frequency range is higher, however, the coefficient at the high frequency range decreases with the increasing frequency and remains constant at 2000 Hz. The behavior is just opposite to the coefficient change of eucalypt wood. Therefore, the thickness of materials decides their acoustic absorption. In addition, the effective thickness of eucalypt wood and the according optimum sound absorption property need a further study.

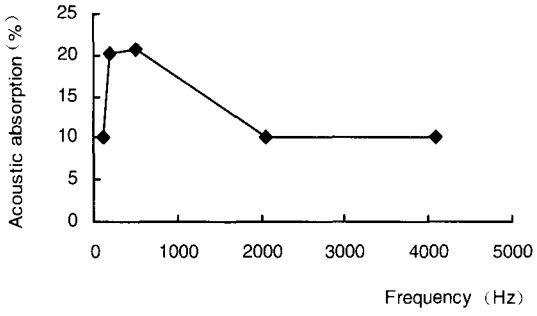

Fig. 2 The relationship of acoustic absorption and frequency of plywood of 3 mm in thickness

Note: the size of the plywood: 1.21 m ×1.52 m; the length between the plywood and the wallboard: 2.5 cm (Watanabe Haruto 1986)

Conclusions and discussion

The average sound absorption coefficient of eucalypt wood is much higher at high frequency. At low frequency the sound absorption coefficient of the tangential-sawn board is higher than that of the radial-sawn board. Therefore, under these two conditions the better absorption effect can be achieved.

Although the difference in sound absorption coefficient among five species of eucalypt wood is not evident at the tested frequency range, the sound absorption property of *Eucalyptus urophylla* at low frequency is better than that of other four species.

The sound absorption property of eucalypt wood of 0.5 cm in thickness is much better. It is necessary to carry out the further research on the effective thickness of eucalypt wood and its optimum sound absorption property, the sound absorption property of the wood treated with different paints and the sound absorption property of eucalypt wood polished and unpolished in future.

References

Bucur, V., Clément A., Bitsch, M. *et al.* 1999.Acoustic properties of resonance wood and distribution of inorganic components of the cell wall [M]. Holz als Roh-und Werkstoff, p103-104.

Ma Dayou. 1983. Acoustic science manual [M]. Beijing: Science Press, p470-477. (in Chinese)

Obataya, E., Umezawa T., Nakatsubo, F. *et al.* 1999. The effects of water soluble extractives on the acoustic properties of reed (*Arundo donax* L.) [J]. Holzforschung, **53**(1) p63-67.

Shang-Tzen Chang, Hui-Ting Chang, Yan-San Huang *et al.* 2000. Effects of chemical modification reagents on acoustic properties of wood [J]. Holzforschung, **54**(6) 669-675.

Shen Jun, Liu Yixing, Tian Zhanli *et al.* 2001. Relationship between Picea genera wood density and sound characteristic parameters [J]. Journal of Huazhong Agricultural University. **20**(2): 181-184. (in Chinese)

Watanabe Haruto. Zhang Qinli, Zhang Qisheng, Zhang Binyuan translation. 1986. Utilization basis for wood [M]. Shanghai: Shanghai Science and Technology Press, p275-279. (in Chinese)